REMARKS

The remainder of this reply is set forth in appropriate subheadings for the convenience of the Examiner.

Telephonic Interview with the Examiner

A telephonic interview was conducted with Examiner Lawrence on Tuesday, April 18, 2006. Two of the three inventors, Prof. Ma and Dr. Engwall, participated in the interview. Applicants and Applicants' attorney would like to thank the Examiner for granting the interview and for his helpful suggestions, which have been incorporated into this Amendment. Among the topics discussed was the distinction between metal materials, on one hand, and metal oxides and metal sulfides, on the other. Applicants present below support, including a Declaration under 37 C.F.R. § 1.132 by Dr. Engwall, one of the inventors of this patent application, for distinctions of metal materials from metal oxides and sulfides, which are often considered to be ceramics, but, regardless, are not considered to be "metals" or "metallic."

Another topic discussed was the difference between dense hydrogen-selective membranes, which are formed of hydrogen permeable materials and selectively allow passage across the membrane of hydrogen gas, and porous layers of hydrogen permeable material, which, although constructed of a hydrogen permeable metal, have open pores and, therefore, are not selective in passage of gas across the layer. As requested by the Examiner, Applicants have provided a Declaration by Prof. Ma that describes the different mechanisms between gas-selective, such as hydrogen gas-selective, permeation through a metal, and non-selective diffusion of a gas through a porous layer. Further, as discussed during the interview, Applicants' specification defines, at, for example, page 6, line 25 through page 7, line 12, dense gas-selective membrane as being, *inter alia*, "substantially free of defects such as open pores, holes, cracks and other conditions that impair the gas selectivity of the composite gas separation module by allowing passage of an undesired gas." Therefore, Applicants have clearly distinguished between dense hydrogen selective membranes and porous layers of hydrogen selective materials.

Rejection of Claims 47-57 Under 35 U.S.C. § 112, Second Paragraph

Claims 47-57 are rejected under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicants regard as the invention. In particular, Claims 47, 51 and 56 are regarded by the Examiner as indefinite because they state that the "porous layer of hydrogen permeable material is selectively permeable to hydrogen gas, however the remainder of the claims 1-46 in the specification refer to the dense or solid layer being selectively permeable to hydrogen, while the porous layer is not selectively permeable." Remaining Claims 48-50, 52, 55 and 57 are rejected for depending from a rejected parent claim.

Claims 47, 50, 51 and 56 have been amended to substitute the phrase "solid layer" with the phrase "dense hydrogen-selective membrane." Support for this amendment can be found in the specification at, for example: page 12, lines 24 through page 13, line 3, and page 16, lines 22-30 for Claim 47; page 6, line 25-28 and page 7, lines 27-28 for Claim 50; page 3, lines 24-27 for Claim 51; and page 3, lines 19-23, and page 6, lines 25-26 for Claim 56.

As amended, the pending rejected claims employ terminology that comports with that used in originally filed Claims 1-36, which distinguish between a "gas-selective material," such as a hydrogen-selective material, and a "dense, gas-selective membrane" of "gas-selective material," which is described at page 7, lines 19-29, and refer to an intrinsic property of the material. A dense gas-selective membrane, described at page 6, line 28 through page 7, line 12, is a configuration of a gas-selective material in the form of a membrane, whereby, as stated at page 7, lines 3-5, "the dense gas-selective membrane is not materially breached by regions or points which do not have the desired gas selectivity properties of the gas-selective material."

Further, Claims 47, 51 and 56 have been amended to more clearly state the presence of a porous layer of a hydrogen permeable material and, separately, the presence of a dense hydrogen-selective membrane in contact with the porous layer of hydrogen permeable material. Support for these amendments is the same as that listed above with respect to substitution of the phrase "solid layer" with the phrase "dense hydrogen-selective membrane."

As amended, pending Claims 47-51 and 54-57 meet the requirements of 35 U.S.C. § 112, second paragraph.

Rejection of Claims 40, 42-44 and 47-57 Under 35 U.S.C. § 112, First Paragraph

Claims 40, 42-44 and 47-57 stand rejected under 35 U.S.C. § 112, first paragraph, as failing to comply with the written description requirement.

In response to the rejection, Applicants have cancelled Claims 43, 52 and 53. With respect to Claims 40, 42 and 44, Applicants maintain that the claims, as written, are fully supported by the specification for the reasons stated in the amendment filed on January 19, 2006. Claims 47, 51 and 56 are supported in the specification, as recited in Applicants' response to the Examiner's rejection under 35 U.S.C. § 112, second paragraph, above. Claims 48-50, 52-55 and 57, which are dependent from rejected Claims 47, 51 and 56, are also fully supported in the specification for the same reason.

Provisional Rejection Under Judicially-Created Doctrine of Obviousness-Type Double Patenting

Claims 1-8, 12, 13 stand 36-39 stand provisionally rejected under the judicially-created doctrine of obviousness-type double patenting as being unpatentable in view of Claims 27 and 31-39 of co-pending application number 10/804,847.

Applicants will address the issue with respect to obviousness-type double patenting upon resolution of remaining issues in this application.

Rejection of Claims Under 35 U.S.C. § 102(b)

The Examiner maintained previous rejections over Edlund '278, Peachey *et al.* '708, Bossard '542, Drost *et al.* '298 and Ma *et al.* (U.S. 6,152,987) under 35 U.S.C. § 102(b) and also under 35 U.S.C. § 103(a) in view of Ma *et al.* '987.

In response to Applicants' argument that Edlund '278 fails to disclose a porous layer of hydrogen permeable material in contact with and deposited on a solid layer of hydrogen permeable material, the Examiner stated that "the intermediate layer of Edlund anticipates the porous layer and the membrane layer anticipates the solid layer."

The Examiner, however, is incorrect in stating that the intermediate layer of Edlund '278 anticipates the porous layer of Applicants' Claims 47, 48, 50 and 51, which stand rejected under 35 U.S.C. § 102(b) as being anticipated by Edlund '278. The rejected claims include a distinct

porous layer of hydrogen permeable material in addition to a dense hydrogen-selective membrane in contact with the porous layer. There is no disclosure or suggestion in Edlund '278 of a porous layer of hydrogen permeable material (e.g., palladium, vanadium, tantalum or niobium), as required in Applicants' rejected claims 47, 48, 50 and 51. Therefore, Edlund '278 does not anticipate Applicants' method of purifying hydrogen gas, as set forth in those claims.

The Examiner apparently is not distinguishing between porous layers that are formed of a hydrogen permeable material, and hydrogen-selective membranes formed of a hydrogen permeable material. As discussed above, Applicants define, at page 6, line 28, through page 7, line 3, a "dense gas-selective membrane":

> A "dense-gas selective membrane," as that term is used herein, refers to a component of a composite gas separation module that has one or more layers of a gas selective material, i.e., a material that is selectively permeable to gas, and that is not material breached by regions or points which impair the separation of the gas by allowing the passage of an undesired gas.

An example of a dense gas-selective membrane is a dense hydrogen-selective membrane, as described at page 7, line 5-9:

> An example of a dense gas-selective membrane is a dense hydrogen-selective membrane that is substantially free of defects such as open pores, holes, or cracks and other physical conditions that impair the gas selectivity of the composite gas separation module by allowing the passage of an undesired gas.

Therefore, the presence of pores, such as would be the case, by definition, in a porous membrane of hydrogen selective material, would not constitute a dense hydrogen-selective membrane as defined by Applicants.

Further, as requested by the Examiner during a telephone interview conducted on Tuesday, April 18, 2006, Applicants have provided a Declaration by Prof. Ma under 37 C.F.R. § 1.132, describing the difference between porous membranes, that do not provide for selective passage of gas, and "dense membranes" of gas-selective materials, that do. Prof. Ma, as stated in the Declaration, obtained his Sc.D. in Chemical Engineering from the Massachusetts Institute of

Technology (MIT) in 1967 and has been a Professor at Worcester Polytechnic Institute since that time. He is the author of over 120 technical papers. He has been the Director of the Center for Inorganic Membrane Studies since 1987. Prof. Ma states in the attached Declaration that "a porous membrane is a thin film layer containing pores of various shapes," and that, "[i]n the membrane research field the term 'dense membrane' has become generally synonymous with a non-porous membrane." Prof. Ma also states that the "membrane literature is replete with references which use the term 'dense membrane' this way" and provides an example from Fundamentals of Inorganic Membrane Science and Technology, Ed. Burggraff, A.J., *et al.*, Elsevier (1996), which states:

> 2. Dense Metal Membrane Reactor
>
> . . . .
>
> Pd together with a handful of other metals is permeable to hydrogen but virtually impermeable to other gases and, of course, liquids. The diffusion process through Pd, furthermore, is an activated process and at high temperatures such membrane show very reasonable permeance.

Prof. Ma provides another example, from page 126 of Membrane Separation Systems, Recent Developments and Future Directions, Baker, R.W. *et al.*, Noyes Data Corporation (1991), which distinguishes between "dense metal membranes" with "Microporous metal membranes":

> 1.3 CERAMIC AND METAL MEMBRANES
>
> 1.3.1 Dense Metal Membranes
>
> Palladium and palladium alloy membrane can be used to separate hydrogen from other gases. Palladium membranes were extensively studied during the 1950'2 and 1960's and a commercial plant to separate hydrogen from refiner off-gas was installed by Union Carbide. [46, 47] The plant used palladium/silver alloy membranes in the form of 25 μm-thick films.
>
> . . . .
>
> 1.3.2 Microporous Metal Membranes
>
> . . . The membranes have a tightly controlled pore size distribution and can be produced with pore diameters ranging from 0.02-2.0 μm.

Prof. Ma explains in his Declaration that "a dense membrane does not contain any pores and permeation is through solution diffusion, whereby gas transport occurs when gas molecules first dissolve into a membrane, and then diffuse across it." Prof. Ma then explains in his Declaration the specific mechanism of particular hydrogen-permeable, metals, such as palladium, vanadium, tantalum and niobium.

Professor Ma further states that one skilled in the relevant art would not consider the porous intermediate layer (3) of Edlund '278 to be a porous layer of hydrogen permeable material, nor would one skilled in the relevant art consider porous intermediate layer (3) of Edlund '278 to be a dense hydrogen-selective membrane.

With respect to rejection of Claims 1, 12, 13, 15, 25-29, 35, 47, 49, 50 and 56 under 35 U.S.C. § 102(b) as being anticipated by Peachey *et al.* '708, the Examiner stated that, contrary to Applicants' argument, the intermediate metal oxide or sulfide layer, porous metal substrate and hydrogen permeable layers disclosed in Peachey *et al.* '708 anticipate Applicants' claimed arrangement. During the telephonic interview, summarized above, the Examiner requested the Applicants provide support for distinguishing between a "porous metal" layer, as employed in the pending claimed invention, and "porous metal oxide or sulfide" layer, as disclosed in Peachey *et al.*

The intermediate metal oxide or sulfur layer disclosed in Peachey *et al.* '708 does not anticipate the intermediate porous metal layer of Applicants' claimed invention because a metal oxide or sulfide layer is not considered to be a metal layer. Evidence can be found for the distinction between metal oxides or sulfides, and metal materials in, for example, common technical dictionaries, such as in the definition of "ceramics" found in McGraw-Hill Dictionary of Scientific and Technical Terms (Exhibit A), wherein metal elements are included, but the compounds and ceramics of which they are a part are not considered metals themselves:

> Ceramic [MATER] 1. Inorganic, nonmetallic materials processed or used at high temperature, generally including **oxides**, nitrides, borides, carbides, silicides, and **sulfides**. Intermetallic compounds such as aluminides and beryllides are also considered ceramics, as are phosphides, and antimonides and arsinides.

(Emphasis added.)

Further, one of the named inventors, Dr. Engwall, has provided a Declaration under 37 C.F.R. § 1.132, describing the difference between "metals" and "sulfides." Dr. Engwall has a Ph.D. in Chemical Engineering from Worcester Polytechnic Institute, and is a Senior Research Engineer at Shell International Exploration and Production in Houston, Texas. As stated by Dr. Engwall in his Declaration, sulfides and oxides are compounds and are not considered to be metals or metallic. Dr. Engwall further states that the distinction can be found in differences in disposition of valence electrons:

> All sulfides and oxides have their valence electrons participating in either covalent or ionic bonding. In contrast, the valence electrons of adjacent atoms in metallic substances are delocalized and loosely shared between larger numbers of adjacent atoms.

Dr. Engwall specifically states in his declaration that the intermediate metal oxide and sulfide layers disclosed in Peachey *et al.* '708 would not be considered to be intermediate metal layers because metal oxides and sulfides are not considered to be metal materials.

In addition to the general understanding by those of skill in the art that metal oxides and metal sulfides are not considered to be metal materials, Applicants clearly distinguish between metal oxides and sulfides, on one hand, and metal materials on the other. For example, at page 2, line 26 through page 3, line 2, Applicants distinguish ceramic substrates as being more brittle than metallic substrates:

> One solution to this problem has been to use a ceramic substrate, which tends to exhibit less diffusion of substrate components into the hydrogen-selective metal membrane than a predominantly metallic substrate. However, ceramic substrates are typically more brittle than predominantly metallic substrates. Further, ceramic substrates can be more difficult to fabricate and also can be more difficult to join to other components in a gas separation system.

Therefore, an intermediate layer of a metal oxide or metal sulfide would not be considered by one skilled in the art to anticipate an intermediate porous metal layer, nor does any portion of Applicants' specification contemplate ceramic materials as being embodiments of intermediate

porous metal layers of the claimed invention. Therefore, Peachey *et al.* '708 does not anticipate Applicants' claimed apparatus or method.

The Examiner maintained rejections under Claims 36-39, 41, 47, 49-52 and 54-57 under 35 U.S.C. § 102(b) as being anticipated by Bossard '542 because, according to the Examiner, "there is nothing in the specification defining the claimed terms in a way that would limit them to exclude a layer that is simply porous to hydrogen." According to the Examiner, Bossard '542 anticipates Applicants' claimed invention because hydrogen can pass through the mesh layers disclosed in Bossard '542.

The claims rejected by the Examiner in view of Bossard '542 all include distinct layers: a first porous layer made from hydrogen permeable material, and a solid layer of a hydrogen permeable material disposed on the first porous layer and in contact with the first porous layer. In order to clarify these claims, use of the phrase "a solid layer of a hydrogen permeable material" in the rejected claims has been substituted with the phrase "dense hydrogen-selective membrane." Support for the claim amendments can be found throughout the specification and the figures. The amended claims comport with originally filed Claims 1-35, which employ the phrase "dense hydrogen-selective membrane" when referring to a solid continuous layer of a hydrogen-selective material, in contrast to a layer that is porous and, therefore, not selectively permeable to hydrogen or another gas, although formed of material that is intrinsically gas-selective, such as a hydrogen-selective material.

Professor Ma states in his declaration that one skilled in the relevant art would not consider the mesh layers of Bossard '542 to be porous layers of hydrogen permeable material, nor would one skilled in the art consider the mesh layers to be dense hydrogen selective membranes.

Claims 1, 10, 13, 15, 25-29, 35, 47, 49, 56 continue to stand rejected under 35 U.S.C. § 102(b) as being anticipated by Drost *et al.* '298. In particular, the Examiner stated that "the intermediate layer of Drost *et al.* '298 must necessarily be porous because paragraph 39 states that the layers can be of a material that has a good permeability for hydrogen." The Examiner further stated that "[h]ydrogen must pass through pores in the layer in order for the device to function, even if the pores are molecular in nature."

Professor Ma states in his declaration that one skilled in the relevant art would not consider the intermediate layer (9) of Drost '298 to be a porous layer of a hydrogen permeable material.

Even in the event that one skilled in the art might consider a continuous layer that is selectively permeable to hydrogen, or some other gas, to be "porous" by envisioning the presence of pores that are "molecular in nature," as described above, Applicants in their specification clearly distinguish between "porous layers" and "dense gas-selective membranes." Conversely, therefore, a porous layer, although possibly formed of a gas-selective material, would have open pores that would prevent gas-selectivity. Applicants' claimed invention includes combinations of porous layers, some of which are formed of gas-selective materials, and dense gas-selective membranes of gas-selective materials that, in contrast to the porous layers, permit only selective passage of gas.

There is no disclosure or suggestion in Drost *et al.* '298 of Applicants' claimed combination of an intermediate porous layer and a dense gas-selective membrane. Diffusion barrier layer (9), although possibly formed of a gas-selective material, is not "porous" as that term is employed by Applicants. Therefore, Drost *et al.* '298 do not anticipate Applicants' claimed invention.

Claims 1-3, 9, 10, 12-16, 25-31, 34, 35, 47-49 and 56 continue to stand rejected under 35 U.S.C. § 102(b) as being anticipated by Ma *et al.* '987. In addition, Claim 19 is rejected under 35 U.S.C. § 103(a) as being unpatentable over Ma *et al.* '987. With respect to Applicants' argument that Ma *et al.* '987 fails to disclose an intermediate porous metal overlying a porous metal substrate, the Examiner stated that Ma *et al.* '987 disclose a "a porous metal substrate (12), a porous metal oxide intermediate diffusion layer deposited on a substrate, and a membrane layer deposited on the intermediate layer," as the basis for maintaining the novelty rejection.

As discussed above, as generally understood in the art and as the term is employed by Applicants, "metal oxides" are considered to be ceramics and "nonmetallic" in nature. As stated by Dr. Engwall in his Declaration, one skilled in the relevant art would not consider the oxidized intermediate layer 14 of Ma *et al.* '987 to be an intermediate porous metal layer. Further, as stated at Col. 3, lines 46-54 of Ma '987:

> Oxidized intermediate layer **14** is a ceramic material formed when a metal of substrate **12** is oxidized in an oxidation-reduction reaction with, for example, oxygen, nitrogen or carbon. As used herein, the term, "oxidize," refers to the process of taking an electron away from a reducing agent in an oxidation-reduction reaction. The concentration of the metal that is to be oxidized at the surface of the substrate must be substantial.

None of the embodiments disclosed by Applicants in the current application employ an oxidized intermediate layer (i.e., a ceramic). Therefore, Ma *et al.* '987 do not anticipate Applicants' claimed apparatus or method. Ma *et al.* '987 further do not suggest use of a metal intermediate porous layer. Therefore, there is no disclosure or suggestion of Applicants' claimed invention by Ma *et al.* '987.

Incorporation of Essential Material by Reference

The Examiner objected to reliance by Claim 43 on incorporation by reference of material from the U.S. provisional patent application number 60/457,061.

Claim 43 has been cancelled, thereby obviating this objection.

Allowable Subject Matter

The Examiner stated that Claims 17, 18, 20-24, 32, 33, 45, and 46 are objected to as being dependent on a rejected base claim, but would be allowable if rewritten in independent form, including all of the limitations of the base claim and in the intervening claims.

In view of the arguments made above, it is believed that amendment of these claims is not necessary and that the claims, as listed and amended in this reply, are allowable, including the referenced claims objected to by the Examiner, without further amendment.

SUMMARY AND CONCLUSIONS

Claims have been cancelled or amended, as necessary, to overcome rejections under 35 U.S.C. § 112, first and second paragraphs. As amended, the claims meet the requirements of 35 U.S.C. § 112, and §§ 102 and 103 in view of the references cited by the Examiner. Therefore, Applicants respectfully request reconsideration and withdrawal of all outstanding rejections and objections to the claims. If the Examiner feels that an additional telephone conference would expedite prosecution of this application, he is invited to call Applicants' undersigned attorney.

Respectfully submitted,

HAMILTON, BROOK, SMITH & REYNOLDS, P.C.

By_____

N. Scott Pierce
Registration No. 34,900
Telephone: (978) 341-0036
Facsimile: (978) 341-0136

Concord, MA 01742-9133
Dated: 5/24/06